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R&ROS TECHNIQUE APPLIED TO A MEDIUM SCALE INDUSTRY FOR TRANSFORMER LOAD MANAGEMENT - A CASE STUDY

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ABSTRACT

The need for Power System Planning and Management has increased enormously today. Resources crunch have made the availability of power meager to meet the demand. Power shortage is not only endemic in India but also in the world – as demand always lags with respect to supply a time factor also plays a role in bridging the gap between demand and supply. To bridge this gap, random load shedding is the usual method adopted by the supplier of electrical energy, which discourages the consumer's interest. To overcome this problem recently the concept of Demand Side Management technique has emerged and is being applied throughout the world. This paper deals with the DSM technique of Resized and Revised operation Schedule taking into consideration the load curve of a transformer. The increase in the energy efficiency of equipment is quantified in terms of Transformer Utilization Factor. A considerable increase in efficient energy utilization and reduction in core losses has been observed.

KEYWORDS: DSM: Demand Side Management, TUFB: Transformer Utilization Factor before DSM, TUFA: Transformer Utilization Factor, PLB: Power Losses before DSM & PLA: Power Losses after DSM.

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A CASE STUDY

1. INTRODUCTION

The most flexible, unavoidable and unsubstitutable form of energy in the modern era is electrical energy. It is a crucial resource for all Nation building activities, which keeps the country's wheels on progress by contributing to overall economic growth [1-2]. The growth rate of a country is measured in terms of per capita consumption of electrical energy. The generation of electric power is limited due to various constraints, whereas the demand is ever increasing [3-5].

It is mandatory to utilize the energy available optimally and efficiently. The concept of DSM technique has evolved in the late 1980's as a trend in power system management [6-9]. It provides mutual benefits for both consumers & suppliers by increasing the energy efficiency of the system. The emerging concept of DSM is gaining momentum in power systems management worldwide. Load management is designed to influence the timing and magnitude of consumer's use of electricity [10-13]. This method mainly includes peak clipping during the system critical conditions, valley filly and load shifting. This load management includes the use of energy storage, load cycling and modification of process characteristics changing the pattern of demand [14-15]. Energy conservation is concerned with those actions which reduce the total energy consumption. Examples of energy conservation include the use of more or better loss prevention method, better efficiency and the curtailment of activities to reduce the overall consumption of electrical energy [16-17]. Load shedding is the procedure by which parts of power system are interrupted according to a predetermined schedule to prevent the overall block out of the entire system due to

over loading, without considering the inconvenience caused to the customer.

The methods discussed above will take care of the interest of the supplier side only without considering the problems of the consumers into account, which is not acceptable, because the ultimate aim of any advancement in technology is to satisfy the consumer. This has forced the power engineers to think of other innovative technological developments to meet the consumer demand either partially or fully, this led to much advancement in the power sector. Among the various advancements in the power sector, Demand Side Management in power systems is latest technology. The concept of DSM was developed in mid 1980’s to meet the problem faced by both supplier as well as consumer [18]. DSM is broader in scope than either load management or energy conservation by including the alternative programs designed to build load as well as to reduce the load [16]. The main objective of the present work is to introduce the concept of DSM and a detailed implementation of the following DSM techniques to an industrial consumer [15].

- End Use Equipment Control
- Load priority Technique
- Peak Clipping and Valley Filling
- Differential Tariff
- Resizing and Revised Operation

DSM benefits: The various DSM benefits from both supplier and consumer point of view are as follows [13].

From Supplier’s point of view:

- By avoiding unscheduled outages, continues supply will be provided.
- Better quality (Voltage magnitude and frequency).

From Consumer’s point of view:

- Better quality of power supply in terms of voltage and frequency.
- Reduction in unscheduled outages.
- Considerable reduction in consumer electricity bill.

2. PROBLEM STATEMENT AND METHODOLOGY

The proposed work is based on the application of few DSM techniques. For this purpose, a local major industrial consumer having various categories of loads has been considered. Existing power consumption pattern has been recorded prior to the application of DSM techniques. From this load pattern, it is observed that the power consumption is beyond permitted maximum demand during some hours of the day and also there are deep valleys during certain operating hours. Thus, load curve is found to be highly uneven, which is undesirable from both supplier as well as the consumer point of view. Load curves with production schedules for a period of six days, including the typical day which recorded the maximum demand for that particular month are collected from the industry. For such load pattern, DSM techniques have been applied. The priorities of various sections of loads are identified in consultation with the concerned superintendents. The improved load curve is highly desirable feature from supplier’s point of view. Even, the consumer will be benefited from the improved

load pattern, thereby improving supply quality in terms of operating voltage. In addition, the supplier's equipment efficiency is also improved in terms of transformer utilization factor after implementing resizing operation and revised operation schedule technique.

With this proposed DSM technique, the transformer core losses of the distribution transformers at Sub-Stations can be minimized and it can be evaluated through Transformer Utilization Factor (TUF) before and after DSM techniques.

3. CASE STUDY

The industry selected for investigation is NRKR Textiles Private Limited, which is located at Rajahmundry, East Godavari District. It was established in 2004.

There are three transformers located in Sub-Station of the industry, having one 950 kVA and two 500 kVA. The incoming line with 11 kV is feeding the industry from the APTRANSCO which is split into two 3- phase feeders, one given to 950 kVA transformer and the other given to the two 500 kVA transformer and the one line diagram is shown in figure 1.

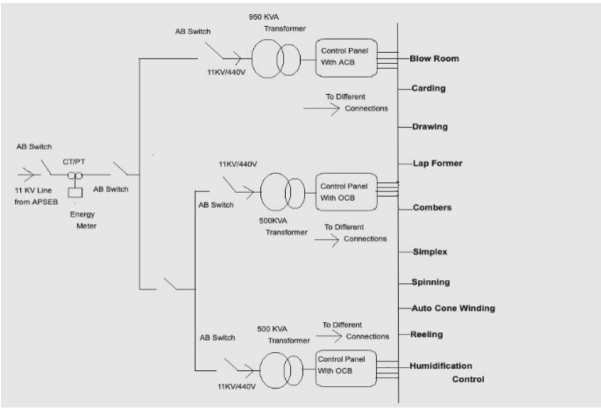

Figure 1: One line Diagram of the Industry.

The three transformers with three control panels which are connected to all load sections in the industry. The 950 kVA control panel having Air circuit breaker and the other two 500 kVA control panels is having Oil circuit breakers. There are a number of motors used in each load section. The type of motor is squirrel cage induction motor.

The application of DSM technique for the proposed problem involves the following steps:

- *Substation loading data.*
- *Data Analysis.*
- *Application of DSM technique.*
- *Payback period and Rate on investment*

a). Substation Loading Data

Table 1 shows the loading data of the three Power Transformers on a particular day for 24 hours as collected from the substation daily log sheets.

b). Data Analysis

Defining a new term called 'Transformer Utilization Factor' does the analysis of this data, and the energy efficiency of the system has been quantified in terms of this new term. Transformer Utilization Factor (TUF) can be defined as "The Ratio of Actual Energy delivered by the transformer to the energy that the equipment can deliver had it been loaded with a constant load equal to its rated capacity for a selected period, say 24 hours. TUF is directly proportional to the energy delivered. This implies higher the TUF greater is the energy delivered and hence increased the energy efficiency of the system in terms of energy delivered. The TUF's of all the three Power Transponders are calculated in each hour. The Transformer Utilization Factor of the transformers is calculated using the data from table.1 using formula from equation (1). The TUF of each transformer for each hour of operation have been calculated and tabulated in table 2.

Table 1: Load Data of a Sub Station

Time in Hours	Load Current in Amperes	Time in Hours	Load Current in Amperes
00 – 01	740	12 – 13	680
01 – 02	720	13- 14	750
02 – 03	720	14 – 15	740
03 – 04	730	15 -16	740
04 – 05	720	16 – 17	740
05 – 06	730	17 – 18	750
06 – 07	730	18 – 19	750
07 – 08	750	19 – 20	760
08 – 09	750	20 – 21	760
09 – 10	750	21 – 22	750
10 – 11	730	22 – 23	730
11 – 12	730	23 - 24	730

$$TUF = \frac{\sqrt{3} \times Voltage\ on\ LV \times current\ on\ LV}{Rated\ VA\ of\ power\ Transformer} \quad (1)$$

Table 2: TUF before DSM

Time in Hours	TUFB	Time in Hours	TUF_B
00 – 01	56.66	12 – 13	52.07
01 – 02	55.13	13 – 14	57.43
02 – 03	55.13	14 – 15	56.66
03 – 04	55.89	15 – 16	56.66
04 – 05	55.13	16 – 17	56.66
05 – 06	55.89	17 – 18	57.43
06 – 07	55.89	18 – 19	57.43
07 – 08	57.43	19 – 20	58.19
08 – 09	57.43	20 – 21	58.19
09 – 10	57.43	21 - 22	57.43
10 – 11	55.89	22 – 23	55.89
11 – 12	55.89	23 - 24	55.89

c). Application of DSM Technique

From the TUF calculations, it is observed that the utilization factors of Power Transformers are very poor / low at each hour, indicating that the energy capacities of transformers have been utilized to a low extent and core losses of big size transformer are meeting throughout the day irrespective of load condition on transformers. This low capacity utilization leads to more iron losses and results in higher operation costs. From the calculation of TUF, it is seen that the transformers

are loaded unevenly throughout the day and hence the TUF are less than 50% for most of the time and also from data collection it is seen that the transformers are connected throughout the day (even though they are lightly loaded). That means core losses are being supplied throughout the day, irrespective of the load on the power transformer and hence the energy efficiency of the system is poor.

Thus there is a lot of scope for improving the energy efficiency of the system. And this is done by the DSM technique adopted without affecting the quality of supply to the consumers.

d). Payback Period (PP) and Rate on Investment (ROI)

Payback and rate on investment are calculated based on the investment made by supplier to purchase new equipment as per DSM suggestions. The Payback period is normally defined as the ratio of capital investment to net returns (4).

$$\text{Payback period} = \frac{A}{(C \times D) - B} \tag{2}$$

Where,

A = Capital cost of energy conservation equipment including Installation cost

B = Annual operating cost

C = Annual Core Losses savings in kWh

D = Projected price in Rs per kWh

Rate on Investment (ROI) is calculated to know at what rate investment returns are getting. The Rate on Investment is defined as the ratio of Net Annual Returns (NAR) to Capital Investment (CI), and it is calculated using equation (3).

$$\text{ROI} = \frac{\text{Net annual returns}}{\text{Capital Investment}} \times 100 \tag{3}$$

4. RESULTS

The DSM technique selected is “Resizing & Revised Operation Schedule (R&ROS). Instead of having one high capacity transformer, two or three transformers of low rating are suggested to be installed. This Resizing & Revised Operation Schedule helps to load each transformer to its rated capacity, whenever it is connected, resulting in higher energy efficiency. For the given load pattern on these transformers the Revised Schedule of Operation is suggested below.

- 00 Hours to 06 Hours 950 kVA, 250 kVA and 50 kVA Transformers are to be connected.
- 06 Hours to 22 Hours 950 kVA, 250 kVA and 100 kVA Transformers are to be connected.
- 22 Hours to 24 Hours 950 kVA, 250 kVA and 50 kVA Transformers are to be connected.

Based on the above suggestions, TUF and losses have been recalculated for each hour of every resized transformer and shown in figure.2, figure.3 and table 3. The core losses are estimated based on the size of the transformer, and data given by the transformer manufacturing companies.

From the above DSM suggestions, the calculation of energy savings for each transformer is calculated using data from table-1 and also saving and payback period are calculated based on data provided by the transformer manufacturers.

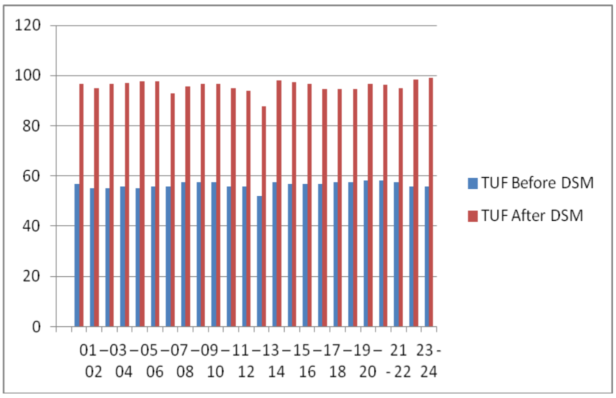

Figure 2: Transformer Utilization Factor before and After DSM.

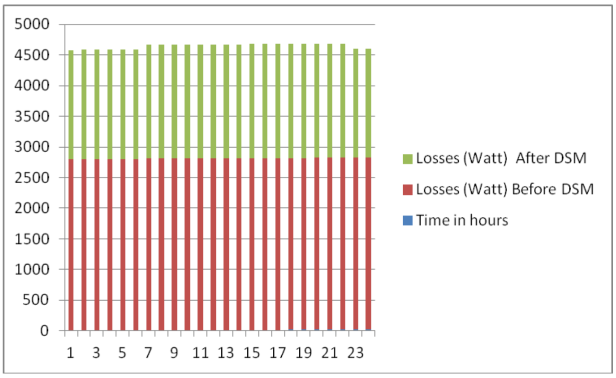

Figure 3: Core Losses of Transformer before and After DSM.

Table 3: TUF after DSM

Time in Hours	TUFA	Time in Hours	TUF_A
00 – 01	96.60	12 – 13	87.85
01 – 02	94.86	13 – 14	97.92
02 – 03	96.60	14 – 15	97.36
03 – 04	97.18	15 – 16	96.80
04 – 05	97.77	16 – 17	94.56
05 – 06	97.77	17 – 18	94.56
06 – 07	92.89	18 – 19	94.56
07 – 08	95.68	19 – 20	96.80
08 – 09	96.80	20 – 21	96.24
09 – 10	96.80	21 – 22	95.12
10 – 11	95.12	22 – 23	98.35
11 – 12	94.01	23 - 24	98.93

After resizing the transformers, a new capital investment is done, after new installation, there is a great improvement in transformer utilization factor and reduction in transformer core losses. The payback and rate on investment are calculations are done below based on the investment made by supplier to purchase new equipment. The Payback period and rate on Investment are calculated using eq.(2) and eq (3).

payback period is calculated by using equation (2).

From the results

A = Rs 1, 20,060,

B = Rs 2500,

C = 16,258.56 kWh,

D = Rs 5/kWh

Payback period = 1.524 Years (1 Years 7 Months)

Rate on Investment (ROI) = 65.61%

5. CONCLUSIONS

Electrical energy is inseparable from economic development and social transformation particularly for a developing country like India. Electrical energy conservation or saving has considered as electrical energy produced. In the proposed work, results after application of DSM alternative technique, the transformer utilization factor improved from 58 % to 98.5 % and the core losses are reduced from 4600 Watts to 2800 Watts per hour, hence net energy savings due to reduction of core losses per day is 432 kWh or 432 units and saving per annum is 15768 units. Hence the approximate revenue savings to the industry will be around Rs.1, 57,680.

The obtained results are submitted to the industry authorities and explained the changes required accordingly in the industry as per DSM recommendations, results of these modifications there is a considerable reduction in the monthly electricity bill.

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